ARM ROBOT USING MACHINE LEARNING

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Abstract -. As human civilization is advancing the usage of robots becoming very common. Robots plays a important role in industrialization and human advancement. Arm robot are one of the most popular robots which are used in industries. These robots are most efficient for manufacturing process. In our robot we have integrated with Arduino micro controller and a esp32 cam module which results in less capital investment for the robot. The esp32 cam enables the robot with real time object detection and the Arduino micro controller is used for robot moment manipulation.
The body the robot is made using 3D printed parts.

***Key Words*:** Arm robot, Arduino micro controller, ESP32Cam module, Object detection, 3D printing.

1. INTRODUCTION

The project aimed to create a functional robotic arm capable of performing various tasks, such as manipulation, assembly, and precise movements, using custom-designed components manufactured through 3D printing using 3D modeling software, specifically CATIA V5, enabled the creation of intricate robotic parts with precise dimensions and complex geometries of robotic arm design.

The robot is integrated with an Arduino microcontroller for control and manipulation. Additionally, it uses an ESP32-CAM module for real-time object detection and manipulation of the robot's position. The robot can be trained on predefined data using machine learning algorithms. The machine learning model is trained using Edge Impulse and is employed for real-time object recognition.

2. LITERATURE REVIEW

These research findings highlight the significance of arm robot for manufacturing process and these robots cost high amount for making these robots. By using micro controller instead of microcomputers or we can reduce the cost of the robot production without reducing the robot functions. Functions such as object detection can be done with esp32 microprocessor. These modules cost less than a microcomputer which reduces the overall cost of the robot.
The design of the robot is made with 3D printing parts which can be custom made for different purposes of the robot. With this integration of arm robot we can use the robot with mechanical gripper, pneumatic gripper or a magnetic gripper for different applications.

3. 3D PRINTING PROCESS

3D modelling process is done using catia v5 software. There are total of 34 individual parts in the arm robot.

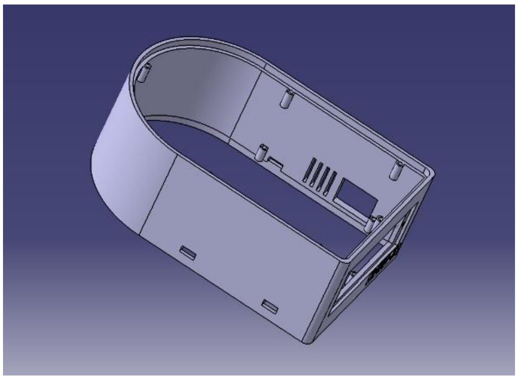

Figure 1 Arm base

First the modelling of robot parts is done by creating a base profile of the component in the part design and by using parts such as pad pocket, etc a complete 3d model of the component is created. The edges of the model is chamfered (in general 2.5mm) to keep the model a smooth finish. For assembling process a screw hole of 3mm diameter is provided at respective places in the model. After completing the model process the is saved in both CATpart and STL format. After creating every component of the arm robot the assembling of the components is done in catia v5 software. After testing the assembly of these components in catia v5 software. The components are sent for 3d printing. Each and every components of arm robot is printed with 30% infill density, try hexagonal infill pattern 0.28mm layer height number of outer layers are 3, number of top layers are 4 and number of bottom layers are 4. For overhanging parts normal supports were used.

The 3d printed parts were assembled by connecting the fitting with M3 boards (Diameter: 3mm, length:15mm). The assembling process doesn't require any nuts or thread inserts only 3d printed holes are used to secure the bolt

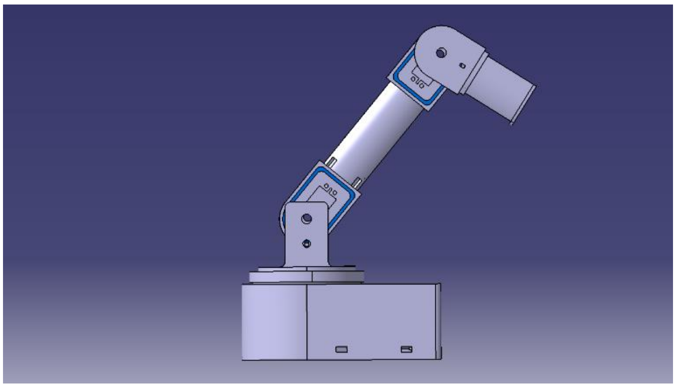

Figure 1 ARM ROBOT ASSEMBLY

4. ELECTRONIC COMPONENTS

The arm robot uses total of four servo motors, one stepper motor, a ardunio uno microcontroller, esp 32 cam module, a servo motor driver (PCA9685). A stepper driver (A4988) and a integrated power supply system in which the output of 12v, 6v and 5v is given from the input of 12v to ampere of power supply.

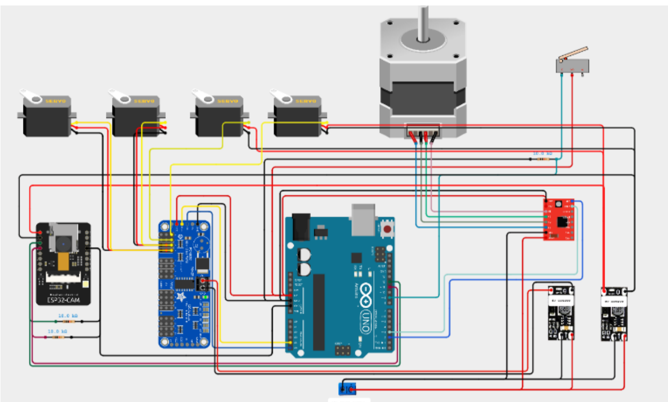

Figure 3 circuit diagram

4.1 ARDUINO UNO

A Arduino uno is a 8 bit ABR microcontroller which is programmed with arduino ide software which uses c and c++ programming languages. Arduino uno is used for controlling robot functions such as homing, position manipulation, end factors(gripper) and analyzing sensor data (esp32 cam)

4.2 ESP32 CAM

Esp32 cam is a 32 bit microprocessor which is also programmed in arduino ide. The esp32 cam module is used for real time object recognisation which uses a edge impulse machine learning module

4.3 SERVO MOTORS

Four servo motors are used for arm robot which gives five degrees of freedom to robot. Three different ratings of servos were used in the arm robot. A torque rating of 30 N-cm is used for arm 1, 25 N-cm for arm 2 and Sg 90 which has torque rating of 2 N-cm for gripper.

4.4 STEPPER MOTOR

The stepper motor located in the base of the arm robot which uses belt drive mechanism. The stepper motor adds another y axis rotational motion which results in a total of 6 DOF for the arm robot.

4.5 STEPPER DRIVER

The stepper driver motor is used to control bipolar stepper motor. It takes 5v logic current from arduino board and 12v from external power supply. Servo motor drive controlling large number of servo motors with arduino board power supply can result in high current load on arduino board which can further damage Arduino board or its functions. By using external servo motor drive we can control has many servo motors for our applications. These module takes input of 6v power supply and it uses I2c communication.

4.6 BUCK CONVERTERS (mini 360)

Two buck converters were used in the arm robot in which both are provided with a input of 12v. The first module gives power output of 6v and second module gives power output of 5v.

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5. MACHINE LEARNING FRAMEWORK

The machine learning model is trained using edge impulse software. The model is supervised machine learning program in which pre-defined labelled data is provided to the model. From this data the model is trained and the parameters of the data is set to gray scale to reduce scale processing time since we are using 32 bit micro processor (esp32 cam).

5.1 DATA ACQUISITION

First a data set of 90 to 100 pictures of each object is taken in different angles and label these pictures has its respective object name(object1, object2)

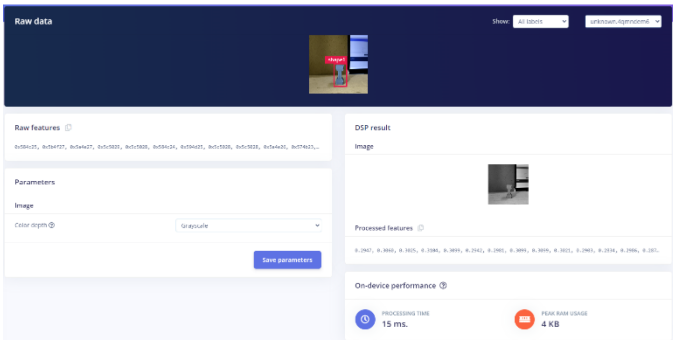

Fig 4 object 1

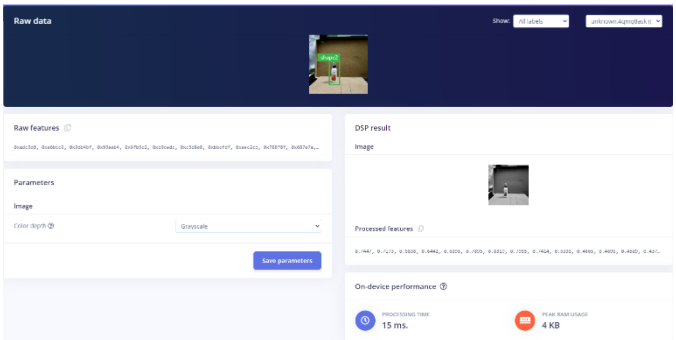

Fig 5 object 2

5.2 MODEL TRAINING

After Aquiring the data parameters are set to gray scale to reduce the processing time of the module. After that a processing block and a learning block added to the machine learning module further a training model FOMO(Faster objects, more objects) mobile net V20.1 is added to the machine learning model. By saving these parameters the machine learning model is trained.

5.3 TRAINING OUTPUT

The trained model for object detection using the ESP32-CAM module yielded promising results with high accuracy and efficiency. During inference, the model achieved impressive F1 scores, with a perfect score (1.00) for background detection, 0.95 for identifying shape 1, and another perfect score (1.00) for recognizing shape 2. These scores reflect the model's robust performance in accurately detecting objects within the camera's field of view.

Inferencing Time: The inferencing time of 982 milliseconds showcases efficient real-time processing, enabling rapid decision-making and object recognition during robot operations.

Peak RAM Usage: The peak RAM usage of 235.5K demonstrates efficient memory management, ensuring optimal performance without excessive resource utilization.

Flash Usage: With a flash usage of 64.3K, the deployed model is lightweight and well-suited for embedded systems, minimizing storage requirements and allowing for easy integration into microcontroller-based platforms.

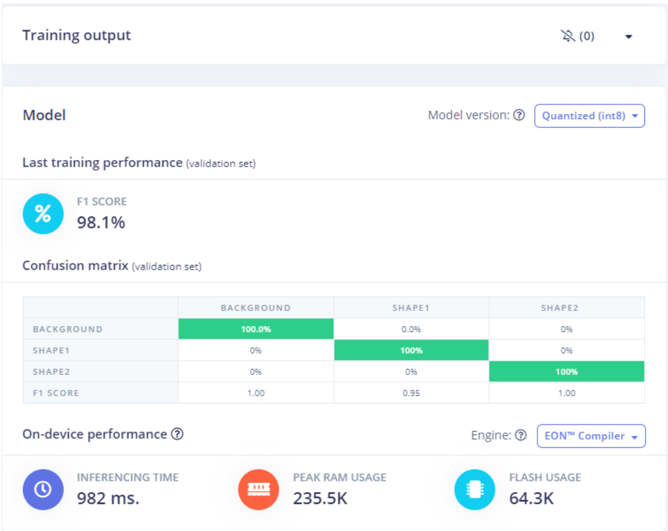

Fig 6 Training output

5.4 ESP 32 CAM CODE OVERVIEW

Camera Model Configuration:

The code defines specific configurations based on the selected cameramodel (CAMERA_MODEL_ESP-_ESP_EYE or CAMERA_MODEL_AI_THINKER). This includes GPIO pin mappings, camera initialization settings, and pixel formats.

Camera Initialization (ei_camera_init())

Initializes the camera module (esp camera init()) with predefined settings (camera config), adjusting parameters such as brightness and saturation if needed based on the camera model.

Image Capture (ei_camera_capture())

Captures a frame from the camera, converts the raw image data (JPEG format) to RGB888 format, and optionally resizes/crops the image to match the input size required by the machine learning model.

Inference Loop (loop())

Perodically captures an image frame (ei camera capture()) and performs inference using the edge impulse machine learning model (run_classifier()). Handles object detection results (result bounding boxes) to identify and process detected objects.

Object Detection Output

Outputs the classification results, including predicted labels (bb.label), confidence scores (bb.value), and bounding box coordinates(bb.x, bb.y, bb.width, bb.height). Controls GPIO pins (digitalWrite()) based on detected object labels to trigger specific actions (e.g., activating relays, LEDs).

6. RESULT

We have integrated the arm robot with arduino and esp32 cam which provide complete robotic arm control and machine learning program which works on real time object detection.

6.1. REAL TIME PERFORMACE: The ESP32 cam module performs object detection with a F1 score 98.1%, 982ms of interencing time, 235.5K of Peak RAM usage and 64.3K of Flash usage.

6. CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In conclusion, the proposed robotic system for the development of low cost arm robot offers a promising solution to the challenges faced by manufacturing industries. This arm robot demonstrates the flexibility of the robot with less capital investment.

During the development process, the important considerations such as module selection, servo motors, stepper motor, 3d printing and selection of 3D printing material (PLA) were done by systematic analysis which results in smooth moment of arm robot and also enhance the structural strength of the robot.

Furthermore, the systematic approach to make arm robot including 3d molding, slicing of the 3d models, 3d printing, assembly of the arm robot, components used, circuit design, cooling system for modules, Comprehensive performance testing validates the efficiency of the developed of ARM robot , highlighting their suitability for a wide range of applications in the .

Moreover, there are the emphasis on cost-effectiveness and also the environmental sustainability underscores the broader implications of this system. By minimizing production costs and optimizing manufacturing processes, the developed ARM Robots offer a viable alternative to traditional robots which uses complicated computing system which cost more for the making robots.

6.2 FUTURE SCOPE

In the future, modules such as micro controller and microprocessors can provide more computing processes which can reduce the usage of micro-computers or computers for robot controlling systems which reduces the overall cost of the robot production. Optimization of manufacturing processes and integration of smart technologies offer opportunities for improved efficiency, reliability, and predictive maintenance. By using different gripper modules such as pneumatic gripper, magnetic gripper and using soft robotics which is a 3d printed gripper and uses material such as TPU for soft robotic gripper.

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